PUBLICATIONS OF THE SCOTTISH COUNCIL
FOR RESEARCH IN EDUCATION

III

CURRICULUM
FOR PUPILS OF TWELVE TO FIFTEEN YEARS
(Advanced Division)

Reprint No. 10
TECHNICAL SUBJECTS

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PANEL ON TECHNICAL SUBJECTS

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TECHNICAL SUBJECTS

Introductory.—This is a Three Years' Post-primary Technical Course which includes Handwork, Technical Drawing, and Mechanics.

If we assume forty periods per school week, and that eight periods are devoted to the proposed course, a suitable allocation of periods would be:—

	1st Year.	*2nd Year.*	*3rd Year.*
Handwork . .	4	4	4
Technical Drawing .	4	2	2
Mechanics . .	..	2	2

The value of *Handwork* is now universally appreciated. Its absorbing interest, high educational value, and corrective qualities render its inclusion in any curriculum for boys essential.

The aim of the *Technical Drawing* scheme is to train boys to produce reasonably good drawings and, what is equally important but much more difficult, to think in three dimensions. The scheme is presented with the intention of arousing the boy's interest. This was often very difficult when the subject consisted largely of abstract problems on points, lines, and oblique planes.

The subject of *Mechanics* appeals to all boys who wish to understand their toys, and to appreciate what they read in the press and in their favourite periodicals about the aeroplane, the racing car, the speed-boat, record-breaking liners, and giant locomotives. It is also most important that the future citizen should have some knowledge of the subject, as trades and industries have become more mechanical and machines have invaded our homes.

One of the aims of this scheme is to give an introduction to some of the fundamental principles of Mechanics. As a school subject it should be of interest and value to boys in the Post-primary Course, for it is treated by experiment and calculation, and it is linked with Technical Drawing and Handwork. The problems also contain interesting applications of simple mathematics, such as should be welcomed for general use.

The schemes should not be considered as definite courses, but as suggested lines of development which may be followed, curtailed, or amplified as equipment and circumstances permit. They have this merit that they have been evolved and tested in actual use, and found to give highly satisfactory results.

HANDWORK

We recommend that the term "Handwork" should be adopted to designate that phase of the Technical Course which is carried out mainly at specially equipped benches.

Although Handwork is being discussed here as an integral part of a Post-primary Technical Course, its educational value is such that it should be an essential part of any well-balanced system of education. Whether it is regarded from the viewpoint of a subject or a method in education, Handwork affords unique opportunities for training in co-ordination of hand and eye, in self-expression, self-reliance, and appreciation of skill.

In view of the great diversity of schemes which must be devised to suit local conditions, it has been deemed inadvisable to give a detailed scheme for a Three Years' Course. In its place the general content of the course has been suggested, supplemented by a list of suitable projects. It is believed that in this way the teacher will enjoy a freedom of action which will enable him to develop a scheme suited to the environment of his school, while at the same time the general standard of attainment expected from the pupil at the end of the course is implied.

In surveying a complete course it is well to keep in mind several factors which limit Handwork projects, *e.g.* the tools to be used, suitable media, and the physical development of the pupils.

In the very early stages of the course the projects should be selected by the teacher, and should be of such a type that pupils must use and acquire dexterity in the manipulation of common bench tools. Generally speaking, wood is the most suitable medium for this purpose. Particularly during this early period it is agreed that all exercises when completed should possess some intrinsic value, even although extreme accuracy has not been attained by the pupils. For example, practice in making joints seems out of place at this stage.

It may be assumed that throughout the whole Three Years' Course the majority of projects will involve the use of wood, either alone or in combination with other media; and it will become the duty of the teacher to make certain that, before the end of the course, each pupil has had an opportunity of attempting all the commoner methods of joining wood and determining where and how to use nails, screws, or glue.

It is also suggested that exercises will be attempted involving simple metal-working operations, which will include soft soldering, wired-edge work, surface filing, riveting, and simple forge work.

Although only wood and metal have been mentioned, there is no intention of excluding any suitable medium.

Where facilities exist for wood turning, every advantage should be taken of this added interest.

Throughout the course there should be discussion and instruction in regard to the properties, the peculiarities, the source of supply, and the distribution of the various materials used.

As Handwork lends itself readily to the project method in education, there are great possibilities in allowing the pupils a freedom in the choice of project to be attempted. In this connection it is well to keep in mind the large number and variety of suitable exercises which may be obtained from domestic, industrial, and technical sources.

Again co-operation among the several departments of a school is always advantageous, and pupils can derive enormous educational advantage by helpful co-operation. For example, exercises can be devised to illustrate problems in physical, electrical, chemical, or engineering science. The value of design in all forms of Handwork should be fully realised. It embraces considerations of materials and tools—their possibilities and limitations as affecting form, construction, and decoration, and its worth as design is relative to the fitness of the article for its purpose. Evidence of thought in form as well as construction should be apparent in all work carried out, and opportunity should be given the pupil to express some of his own ideas in his work. In this way the educational value is enhanced, interest increased, and appreciation developed.

Throughout the course in Post-primary Handwork it should be kept in mind that each project should be designed to serve a definite purpose, and thus the finish of the article must be considered. In many cases it will be necessary to apply a suitable protective or preservative, such as varnish, stain, or wax polish.

Drawing.—Except in the very early stages, drawings of the exercises should be made before the problem is attempted practically. At the same time, it is advisable that periodically throughout the course working drawings should be made from dimensioned free-hand sketches as well as from pictorial views, such as are now common in periodicals widely read by boys.

Training in ability to interpret and construct from working drawings must be an essential part of the course.

The Problems.—In formulating problems for construction certain conditions should be fulfilled. The problems should be presented in sufficient variety to sustain interest and attention; have close connection with other school studies; show good design in construction and form; afford ample opportunity for self-expression; and be within the powers of the boy to accomplish successfully.

Such problems might be selected from the following sources:—

1. Home Interests. (a) *Wood, and Wood and Metal.*	Key label, pencil sharpener, pot stick, straight edge, rule, thread and wool winder, window wedge, teapot stand, match holder, hot-plate stand, paper knife, photo frame, watch stand, toothbrush rack, pipe rack, tumbler holder, inkstand, nail box, soap box, salt box, knife, fork, and spoon box, soap and sponge box, blotter, letter rack, newspaper rack, account file, pin tray, toilet tray, coat and trouser hanger, trouser stretcher and press, tie press, towel roller, book rack, stationery rack, boot rack, egg stand, egg holder, cutting board, bread board, colanders, box bank, collar box, tea box, casket, attaché case, music case, glove box, tool box, cake stand, tea tray, candlestick holder, foot stool, stool, plant stool, plant table, window table, card table, mantel book-shelf, combined book and stationery rack, bookcase, revolving bookcase, writing desk, smoker's cabinet, medicine cabinet, music cabinet, music stool, etc.
(b) *Wire.*	Chain, egg switch, egg lifter, egg boiler, toasting fork, paper file, toilet fitment, silk winder, tumbler holder, potato masher, tweezers, card holder, test-tube grip, tea and coffee strainer, spoon with wire handle, candle and lamp shades, flower-vase stand, soap and sponge rack, toast rack, hanging plant holder, wall-plate holder, cake cooler, potato-chip basket, fish boiling tray, etc.
(c) *Tin Plate.*	Match-box cover, letter rack, toothbrush rack, small tray, biscuit cutter (various shapes), grater, bank, taper holder (various shapes), birds' drinking trough, birds' bath, milk can, pint measure, filler, scoop, dust pan, oil can, cake tin with false bottom, fish slice, loaf tin, fancy boxes, candlestick holder, vegetable strainer, soap and sponge holders, etc.

(d) *Constructive Repoussé Work in Brass, Copper, or Aluminium Sheet.*	Initial plates, name plates, finger plates, serviette rings, small trays—square, oblong, round, and shaped; various box shapes—cigarette box, tea box, jewel boxes; blotters, inkstands, small fern pots, flower pots, table lamps, photo frames, mirror frames, flower vases, sconces, plaques, muffin stands, spoons, decorative shapes for application to wooden objects, straps, hinges, etc.
(e) *Forge and Vice Work in Iron and Steel.*	Cutting, forging, and shaping steel punches for Repoussé Work; hot-iron stand, skewers, poker, coal tongs, small shovel, spring paper clip, iron hinges and fittings of various kinds. *Tools*—Bradawl, screw driver, try-square, marking gauge, mitre block, bevel, cold chisel, nail set, rivet set, calipers, centre punch, flux tray, soldering iron, trowel, paint scraper, wood scraper, small thumb cramps. *Hammered Decorative Iron Work*—Door knocker, letter-box plate, hinges, kerbs, iron holder, coal box, etc.
2. GARDEN AND RURAL INTERESTS. (a) *Wood, and Wood and Metal.*	Seed markers, plant stick, measuring rod, dibble, seed protector, seed and bulb trays, line winder, wooden rakes, drill marker, potato setter, layering stick, ladder, steps, vermin traps, sprays, riddle, forcing frames, cold frames, potting stick, besom, hammer or axe shafts, flower staging, turf beater, dolly peg, boiler lid, strainer, boiler stick, clothes pegs, clothes poles, bucket rest, garden roller out of oil drum filled with cement, wooden bolt for door or gate, wooden spring latch, wheelbarrow, hen coop, fowl pen, trap nest, egg boxes, incubators and foster mothers, garden basket, milking stools, tree protector, wicket gate, field gate, stile, feeding troughs, potato masher, hammock sling, hay rack, manger,

	hurdle and fencing, portable garden tent, bee hive with accessories, dog kennel, dovecot, swing, small bridges. *Rustic Work*—Fern baskets, table, seat, arches for flowers, trellis work, shelter, tool shed, weather vane, rain gauge, etc.
(b) *Forge and Vice Work in Iron and Steel.*	Wire borders, seed markers, ceiling hooks, hold fasts, tub handles, box handles, cinder or path rakes, hoes, garden trowel, hand fork, gate hinges and latches, hooks and eyes, staples, shelf brackets, door bolt, special gate fasteners, fire shovel. *Cart Fittings*—Trace hooks, shaft, staples, cart steps, back hinges, etc.
(c) *Rope and String Work.*	Knots—overhand, Flemish, sailors, weavers, fisherman's, lash; crowning, jar sling; splicing—eye splice, cut splice; grommet, guy roop and strainer, halter, rope ladder. *Rough Mat Making and Netting*—Oval mat, coco mat, woven mat; pea net, hammock, etc.
3. GAMES AND SPORTS, HOBBIES AND PETS. *Wood, Iron, Tin, Steel.*	Table tennis, bagatelle, ring game, ball game, parlour quoits, blow football, croquet mallets and hoops, chess or draught board, rounder bat, cricket bat and stumps, hockey stick, golf clubs, cat and bat, bow and arrows, targets, single sticks, basket ball, nine pins; fishing rod, gaff, landing net, casts; boats and yachts; display cases or cabinets for birds' eggs, stamps, butterflies, coins; dog kennel, rabbit hutch, bantam pen, bird cage, aquarium, camera, house for white mice; camping tent, camp stool, camp bed, pegs, frying pan, boiling pan, tripod, screen, drinking tin, etc.
4. TOYS.	Boomer, trick block, various puzzles, building blocks, boomerang, tumbling clowns, acrobatic clowns, swinging parrot, spinning tops, boxing puppets, jumping kangaroo, doll's house and

	furniture, Noah's ark and animals, scooter, kites, aeroplanes, barrow and spade, jointed dog, waggon, paddle boat, rocking horse, motor car, etc.
5. SPECIAL GROUP WORK AND WORK HAVING A BEARING ON LOCAL INDUSTRIES.	Simple looms, pit cage, ventilating fans, pumps; simple pattern-making and casting in lead; punts, canoes, boats, yachts, and certain parts of ship construction; sheds, shelters, summer-houses, and simple examples in house construction; types of fishing nets, creels, boxes, sails; simple printing press and accessories; Norman castle showing moat, drawbridge, portcullis, etc.; theatre; Roman camp; illustration of two- and four-stroke internal combustion engines, turbine, steam engine; simple bridges; problems of cities—sewage disposal, water supply, lighting, etc
6. OBJECTS INVOLVING SCIENTIFIC PRINCIPLES.	Lever balance, spring balance, dynamometer, lever apparatus, bell-crank lever, leaning cylinder, inclined plane, wedge, pulley frame, magic cylinder, sandmill, windmill, windlass, capstan, hoist, suction pump, cigarette delivery box, pop gun, glove stretchers, pantograph, roof truss, crane, bridge, turbine, steam engine, spectrum, spinning top, hydrometer, clinometer, helicopter, camera, camera obscura, periscope, kaleidoscope, syphon, spray, water wheel, pelton wheel, fountain, water-clock, megaphone, whistles, siren, thermometer, barometer, sextant, shadow clock, blowpipe, heat-bow, hot-air spiral, monochord, one-string fiddle, chimes, gong, dulcitone, ukelele, protractor, liquid measures, rain and wind gauges, rangefinders, steam launch, etc. *Electrical*—Buzzer, bell, induction coil, telephone, telegraph, morse key, battery, night lights, wireless sets, galvanometer, compass, simple electric motors and dynamos, etc.

7. Turning in Wood. Rulers, feet for boxes, etc.; pot stick, glove-finger stretcher, darner, file handle, chisel handle, rolling pin, potato masher, dumb bells, Indian clubs, stool, mallet, tray handles, umbrella handles and knobs, candlesticks, match holders, clock case, lamp stands, cake stands, inkstands, egg cups, finials, taper holders, napkin rings, needle case, boxes, vases, card trays, plates, mirror frames, photo frames, ash trays, various shaped bowls, etc.

TECHNICAL DRAWING

First Year

Plane Geometry

To familiarise the pupil with the properties of the common Plane Figures and to gain experience with rule and protractor, it is suggested that models in cardboard of these Plane Figures be given to each pupil to measure the lengths of the sides and sizes of angles. These with name of figure should be tabulated. The figures might be studied in the following order:—

(*a*) Equilateral Triangle, (*b*) Isosceles Triangle, (*c*) Scalene Triangle, (*d*) Square, (*e*) Rectangle, (*f*) Rhombus, (*g*) Rhomboid, (*h*) Regular Hexagon, (*i*) Regular Octagon.

These should be drawn later after some experience has been gained in the manipulation of the drawing instruments.

Suggested Exercises.—

(*a*) Bisecting lines of various lengths.
(*b*) Bisecting angles of various sizes.

(*c*) Drawing parallel lines at a given distance apart.
(*d*) Drawing perpendiculars with Tee Square and Set Square, or with two Set Squares.
(*e*) Dividing a line into a number of equal parts.
(*f*) Dividing a circle into 4, 8, 6, and 12 equal parts.

All figures should be lettered with block letters, and their titles printed.

Solid Geometry

Orthographic Projection.—A model of the three co-ordinate planes should be made in paper or preferably in cardboard by each boy, so that he can clearly see the ground lines which he is to draw on his paper.

It would be advantageous if the lettering of the ground lines were the same in all districts, and the following is suggested where the second elevation is drawn in line with and to the left of the plan:—

OX pointing to the right.
OY pointing to the front.
OZ pointing upward.

Give names of the three planes and the meaning of plan, elevation, and end view. At first the position of the end view should always be in line with the elevation, but later this may be varied by drawing the end view in line with plan.

Draw three views of a rectangular block of wood in simplest position. Letter the top right-hand front corner only (a, a_1, a_2) and write down its distance above H.P. in front of V.P., and to the right of 2nd V.P.

A due proportion of time should be spent in an endeavour to get the boy to read his drawing and think in three dimensions. He might be asked to show (1) height, (2) length, (3) breadth, (4) back, (5) front, (6) various specified corners in all the three views. This procedure should be repeated with all solids.

Pictorial Projection.—A pictorial projection of an object gives a much better conception to the untrained mind than can be derived by an examination of three rectangular views. It is, therefore, recommended that this form of projection should be freely used.

Exercises might be given in—

(*a*) Drawing three views from a pictorial view.
(*b*) Drawing a pictorial view from three views.
(*c*) Sketching a dimensioned pictorial view and then drawing three views.

Developments.—In order that the boy may be able to make his own models in paper he should develop all the geometrical solids which he draws.

Suggested Objects—

(1) Block of wood.
(2) Triangular prism axis parallel to H.P. and V.P.
(3) Hexagonal ,, ,, ,, ,,
(4) Cylinder ,, ,, ,, ,,
Introduce here the chain-dotted centre line.
(5) Cone standing on H.P.
(6) Small objects made in wood from which own dimensions are taken.
(7) The square pyramid.
(8) The hexagonal pyramid.

Before the pyramids can be developed the subject of true lengths of lines should be discussed and some construction given.

System of Lettering.—An edge or line should be called A, B; its elevation lettered a_1, b_1, its plan ab; and its 2nd elevation a_2b_2.

SECOND YEAR

Plane Geometry

Drawing tangent to a circle from a point

(*a*) On the circumference.
(*b*) Outside the circumference.

Drawing an arc of a circle of given radius to touch two lines at right angles.

Drawing an arc of a circle to touch two lines when angle is not right.

Drawing a circle to touch a straight line and a circle.

These curves (fillets) occur in mouldings and rolled joists, some of which should be drawn.

Solid Geometry

By way of revisal draw three views of some common object in the room. Indicate a point on object by a point in the three views and write down its position from the three planes.

Discuss again height, length, and breadth.

Draw new elevations of selected objects.

Draw new plans of selected objects.

Examples should be graded, starting with straight-line objects, surfaces all flush, then objects standing on a pedestal, and finally curved surfaces.

Simple sections of straight-line geometrical solids, giving the true shapes of sections and developments wherever possible.

Simple section of some familiar object.

To illustrate the lay-out of a working drawing or partial section drawing, draw three views of a hollow cylinder standing on a square slab, one half of each view to be in section. Dimension completely, assume different materials, and use correct section lining.

Draw three partial-section views of the gland of a stuffing box, or other similar object.

THIRD YEAR

Plane Geometry

Construction for ellipse, parabola, and cycloid. Some exercises on the loci of points on simple mechanisms, *e.g.* a point on a connecting rod, Watt's parallel motion.

Construction of plain scales, special attention being paid to the numbering.

Solid Geometry

More advanced work in sections and developments, using the cylinder and the cone.

Suitable exercises are:—

(1) Cylinder standing on H.P., and cut by a plane inclined to H.P.

Drawing new plan to get true form of section.

(2) Cylinder lying on H.P., axis parallel to V.P. and cut by

- (*a*) A plane inclined to H.P. or
- (*b*) A plane inclined to V.P.

Drawing for (*a*) the plan of section and a new plan to get true form of section, and for (*b*) the elevation of section, and a new elevation to get true form of section.

(3) Cone standing on H.P. and cut by planes to give

- (*a*) An ellipse.
- (*b*) A parabola.
- (*c*) A hyperbola.

True shapes of the conic sections should be found by drawing auxiliary views.

The development of the part of cylinder or cone on one side of the cutting plane should be drawn.

Draw three views of a hexagonal nut to fit, say a 3-inch bolt. A new plan of this makes an excellent exercise.

Construction and development of the helix, with examples.

Additional applications of auxiliary views—

(1) Solids inclined to H.P.
(2) Solids inclined to V.P.
(3) Sections of (1) and (2).
(4) True shapes of surfaces like truncated pyramids and sloping roofs pierced by square and round openings.

Examples from building construction—

(*a*) Brick bonds and courses.
(*b*) Outline diagrams and names of various forms of roofs.

Instruments and Drawing Materials.—Drawing boards —½ Imperial size (23 in. × 16 in.). The 3-ply board is excellent.

Tee Squares—½ Imperial size, made of pearwood, the blade to be screwed on top of head to enable set squares to slide over head.

Set Squares—Made of pearwood, 45°, 6-in. side; 60°, one 8-in. side.

Compasses—The type with needle-point and receptacle for piece of hard lead should be used.

Rule—12 in., showing $\frac{1}{10}$ths, $\frac{1}{12}$ths, $\frac{1}{16}$ths, and millimetres.

Protractor—The semi-circular type made of celluloid or brass.

Pencils—H.H. for drawing. H.B. for writing, lettering, and sketching.

Rubber—A good soft variety.

Paper—A good quality cartridge paper. $\frac{1}{4}$ Imperial (15 in. × 11 in.), or $\frac{1}{8}$ Imperial (11 in. × $7\frac{1}{2}$ in.) for First and Second Years, and $\frac{1}{2}$ Imperial (22 in. × 15 in.) for Third Year.

Envelope—It is assumed that pupils should make the necessary envelopes for preservation and retention of drawings.

Notebook—Sketching should be done in a squared-paper exercise book, inch and one-tenths.

MECHANICS

Preliminary Ideas of Force.—Simple illustrations of force, *e.g.* a weight of say 4 lb. is held in the hand. This requires the exertion of a force of 4 lb.

Suspend a weight from a string, and discuss the tension (force) in string.

Study the effect of force on elastic cords and helical springs.

The Simple Lever and Moments of Forces.—By using a uniform rod, pivoted at its centre and having a weight suspended on either side of the pivot, introduce the idea of:

(1) Clockwise and anticlockwise turning.
(2) The moment of force about a point.

Adjust positions of the two weights to get equilibrium, and find that

(3) Clockwise moment=anticlockwise moment.

Repeat the above with several weights on each side of pivot, and find that

(4) Sum of clockwise moments=sum of anticlockwise moments.

This is the "Principle of Moments."

At first Moment of a Force might be defined to be Weight × Length of Arm, but later corrected to Force × Perpendicular Distance.

A large number of numerical examples should be given here with the fulcrum in various positions.

The Bell-crank Lever.—By experiment and calculation find the force applied at end of one arm to balance a weight suspended from end of other arm, the forces to be perpendicular to the arms.

Levers acted on by Inclined Forces.—By experiment and calculation find the balancing force. When calculating the result, the lever should be drawn to scale on paper, the perpendiculars to the forces carefully drawn, and their lengths measured.

Additional Experiments on Levers.—

(1) Find weight of an object of, say, 12 lb. with a rod and a spring balance reading to, say, a maximum of 4 lb.

(2) Suspend the ends of a loaded beam by means of spring balances, and find the supporting forces (end reactions).

The above to be checked by calculation.

Technical Terms which are Expressed in Pounds per Square Inch.—

(1) Builders express the weight of their flooring and roofing material as, say, 40 lb. per sq. ft. Using

this or similar data, what weight would be required to cover an area of, say, 20 ft. by 80 ft.?

(2) Engineers say their steam, gas, and petrol vapour have a pressure of, say, 40 lb. per sq. in. What force would this represent on a piston of diameter of 10 in.?

(3) Civil engineers talk about the intensity of load (stress) in tons per square inch in a rod when it supports a load. What is that stress if you are given the load and section of rod?

Introduce stresses in bars of rectangular, circular, tee, angle, and other sections which have been drawn in the Technical Drawing Class.

Work and Machines.—Before starting the study of machines the measurement and definition of work should be thoroughly explained by a number of examples of the following three types:—

(*a*) Work done in lifting bodies.
(*b*) Work done in drawing bodies along the horizontal, expressing friction in pounds per ton.
(*c*) Work done on an engine-piston, given bore and stroke and intensity of pressure.

Then define a machine as a contrivance, at one point of which a small force, called the Effort, is applied and moves through a large distance. This moves a large force, called the Load, through a small distance.

Measure the displacement ratio (velocity ratio) of some of the following machines by direct measurement and by calculation from the sizes of parts of machine (*e.g.*) :—

(*a*) Simple windlass.
(*b*) Screw jack.

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(*c*) Worm and wheel.
(*d*) Some arrangement of pulleys.
(*e*) Crab winch (later).

Explain and measure, if possible, the "gear" of a bicycle.

Mechanical Advantage.—On one of the above machines place a load, and find the effort to raise it. Using the displacement ratio, find the Work done *by* the Effort and the Work done *on* the Load. Why are they different?

Discuss friction as reason for "lost work," and show how it is not altogether a bad thing, as in certain machines the operative may leave the handle and the load will not run back. The term Efficiency can now be defined as

$$\frac{\text{Work done on Load}}{\text{Work supplied by Effort}}.$$

Friction.—It has been found that friction causes waste of work.

To find something more definite about friction between plane surfaces—

(*a*) In regard to area of surfaces in contact.
(*b*) In regard to pressure between surfaces.
(*c*) In regard to condition of different surfaces.

Show how to get a Friction Constant (coefficient of friction), expressing the state of roughness of the surfaces.

Explain how the constant can be found by tilting the plane until the slider just slips down.

The Parallelogram and Triangle of Forces.—A force has (1) magnitude, (2) direction, and (3) sense, *i.e.* acts one way or the other along the direction mentioned. A line with an arrow-head on it may therefore represent a force.

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The Addition of Forces.—Resultant and Equilibrant by the Parallelogram of Forces by drawing and by experiment.

The Triangle of Forces.—A piece of cardboard or plywood is suspended from two strings passing over pulleys and supporting different weights. From another point of plywood a third string supports a weight. Transfer the directions of the three strings to paper placed behind the plywood, and show they pass through the same point. Draw lines parallel to the three forces, and a triangle is formed. This demonstrates that if three forces keep a body at rest, they must pass through the same point, etc.

It will be instructive now to go back to the bell-crank lever, and show how the "Triangle of Forces" can be used not only to find the force required, but also the reaction at the fulcrum. It can also be proved now that the Friction Constant$=\frac{\text{Height}}{\text{Base}}$ (Angle of Repose Method). Experiments on tension in cords, forces in tie and jib of crane, the inclined plane without friction, etc.

All experimental work should be checked by drawing.

Centre of Gravity.—The subject might be introduced by balancing a non-uniform rod on a straight edge. The weight of the rod must act through the straight edge, or there would be a turning moment in one direction. Now define the Centre of Gravity as the point through which the weight may be regarded as acting. Apply the same method to find C.G. of geometrical figures in cardboard or plywood, taking straight edge in two directions. Some girder and rail sections should also be chosen.

Now drill three holes in the plywood and suspend the plate from a nail through each hole in turn, having a plumb-bob hanging in front. The C.G. will be the point of intersection of the three lines behind the string of the plumb-bob. Check some of the simpler cases by taking moments of areas.

Test by balancing on a pin-point.

Speed.—Conversion from miles per hour to feet per second. Constant speed and average speed. Speed of a man's hand at end of a handle or speed of a crank pin. Given diameter of wheel of a car or locomotive and speed of rotation of wheel in revolutions per minute, find speed of car in miles per hour.

Displacement ratio of shafts connected by belts, friction drive, or toothed gearing.

Horse-power.—Show how to calculate Horse-power:—

(*a*) To raise loads or pump water in a given time through a given height.
(*b*) To draw a train of given weight at a given speed along a level track, given the friction constant.
(*c*) For a steam or petrol engine, given bore, stroke, speed, and intensity of pressure.

Graphs.—Employ graphs where possible, stating the scales used, *e.g.*:—

(*a*) Load and Effort.
(*b*) Load and Efficiency (machine experiment).
(*c*) Friction and Normal Pressure (friction experiment).
(*d*) Force and Distance. Find average height by "mid-ordinate" method. This gives average force. Multiply by length of diagram. This gives work done, if scales are correctly used.

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